PATENT COOPERATION TREATY

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT
(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 3606PTWO	**FOR FURTHER ACTION** See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/EP 03/12781	International filing date *(day/month/year)* 14.11.2003	Priority date *(day/month/year)* 15.11.2002
International Patent Classification (IPC) or both national classification and IPC C23G5/00		
Applicant DANIELI & C. OFFICINE MECCANICHE S.P.A.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 7 sheets, including this cover sheet.

☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of 16 sheets.

3. This report contains indications relating to the following items:

I ☒ Basis of the opinion
II ☐ Priority
III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
IV ☐ Lack of unity of invention
V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
VI ☐ Certain documents cited
VII ☐ Certain defects in the international application
VIII ☐ Certain observations on the international application

Date of submission of the demand 14.06.2004	Date of completion of this report 07.03.2005
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer van der Zee, W Telephone No. +31 70 340-2797

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1, 3, 4, 6, 8, 9, 11-19, 21-26	as originally filed
2, 5, 5A, 7, 10, 20	filed with telefax on 18.02.2005

Claims, Numbers

1-34	filed with telefax on 18.02.2005

Drawings, Sheets

1/20-8/20, 10/20-12/20, 16/20-20/20	as originally filed
9/20, 13/20-15/20	filed with telefax on 18.02.2005

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   ☐ the language of publication of the international application (under Rule 48.3(b)).
   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:
   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-34
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-34
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-34
	No:	Claims	

2. Citations and explanations

   see separate sheet

Re Item V
Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents:

   D1: US-B-6406550
   D2: DE-A-19519544

2. In respect of Article 6 PCT the following is observed.

2.1 The terms "adequate", "sufficient" and "predetermined" in claim **18** are vague and unclear and leave the reader in doubt as to the meaning of the technical features to which they refer, thereby rendering the definition of the subject-matter of said claim unclear, see also the PCT Guidelines, 5.34 and 5.35.

2.2 The term "preferably" in claim **24** has no limiting effect on the scope of this claim and thus the feature "nitrogen and/or helium and/or argon" following the term "preferably" is formally to be regarded as entirely optional, see the PCT Guidelines, 5.40.

3. The following is stated under reference to paragraph 2 of this International Preliminary Examination Report whereby it is to be noted, that unclear features cannot be employed for assessing novelty or inventive step.

3.1 The document D1 is regarded as being the closest prior art to the subject-matter of claim **1**, and discloses (the references in parentheses applying to this document) a dry descaling apparatus for scale removal (see column 2, lines 35-36) from a surface of a metal product (1) comprising
at least one heating area (4) for heating the metal product (1),
at least one reducing area (7) for performing a reaction between a metal-oxide reducing gas and at least the scale,
at least one area (8) for cooling the metal product (1),

first heating means (3) for heating (see column 2, lines 40-51) the metal product (1), second heating means (3,28) for heating (see column 4, lines 36-38 and 55-57) the reducing gas,
means for removing reaction products from the reducing gas after reaction (see column 2, lines 47-55 and column 6, lines 49-63),
means for removing reaction products which are left on the surface of the metal product (1) after treatment (see column 4, lines 23-31, column 5, lines 50-55 and column 7, lines 32-38), and
means for cooling (see column 3, lines 21-23) the metal product (1);
wherein said dry-pickling apparatus comprises
first control means for fluid dynamic control of the boundary layer produced by the flow of said reducing gas over the surface of said metal product (1) wherein said first control means are adapted for generating regular pressure oscillations comprising overpressure and depression areas, which are repeated in succession along the entire surface of said metal product (see column 4, lines 14-23 and column 6, lines 36-44),
the overpressure areas being associated with a reducing gas blowing stage towards the surface of said metal product (see column 4, lines 21-23 and column 6, lines 28-30 and 36-40), and
the depression areas being associated with a reducing gas evacuation phase (see column 6, lines 33-34), and in that it comprises
second control means for controlling reducing gas chemical composition at the blowing stage (see column 6, lines 14-18 and column 5, line 63 - column 6, line 13),
third control means for controlling reducing gas temperature (see column 3, lines 15-17 and column 4, lines 36-43 and 55-56).

The subject-matter of claim **1** therefore differs from this known apparatus in that the depression areas are associated with a reducing gas phase evacuation means downstream of the blowing stage and that it comprises means adapted for purging and recycling reducing gas after reducing operation of the scale.

The subject-matter of claim **1** is therefore novel and claim **1** meets the requirements of Article 33(2) PCT.

The objective problem underlying claim **1** is to achieve improvement of reduction

rates of scale and homogeneous reduction of all points covered with scaling, cf. page 6, lines 6-8 and 12-18 and page 9, lines 17-21, also page 5, lines 6-14 and 25-29 and page 5, line 32 - page 6, line 3.

The solution in accordance with claim **1** is the provision of depression areas which are associated with a reducing gas phase evacuation means downstream of the blowing stage and means adapted for purging and recycling reducing gas after reducing operation of the scale.

Although D2 discloses depression areas associated with a reducing gas phase evacuation means, cf. column 5, lines 15-18 and the figures, the combination of the further features of claim **1** is not disclosed by any of the cited prior art documents.

The skilled person is not hinted at the further combination of means adapted for purging and recycling reducing gas after reducing operation of the scale, with the features of D1 and D2 in order to solve the objective underlying problem.

The subject-matter of claim **1** thus involves an inventive step and meets the requirements of Article 33(3) PCT.

3.2 Claim **18** relates to the use of an apparatus according to one of the previous claims.

It has been established (see paragraph 3.1) that the subject-matter of claim 1 is novel and involves an inventive step and meets the requirements of Article 33(2) and 33(3) PCT. Consequently, the use of said apparatus is to be considered novel and inventive as well.

The subject-matter of claim **18** thus is novel and involves an inventive step and meets the requirements of Article 33(2) and 33(3) PCT.

3.3 Claims **2-17** and **19-34** are all truly dependent claims and also meet the requirements of Article 33(1) to 33(5) PCT.

4. The following is to be noted too:

4.1 The description is not in conformity with the claims as required by Rule 5.1(a)(iii) PCT.

4.2 There appears to be an error in the term "patetent" in the description on page 5, line 3.

4.3 According to Rule 6.3(b) PCT, the features known in combination from the prior art (document D1) should have been placed in the preamble of independent claim **1** (Rule 6.3(b)(I) PCT) with the remaining features being included in the characterizing part (Rule 6.3(b)(ii) PCT).

FeO and Fe_3O_4, Fe_2O_3 and Fe_3O_4.

Sometimes, oxidized products are exposed for prolonged periods of time to industrial and/or sea air. This, leads to considerable rusting (thick layers of complex iron hydroxides (millimetres). Therefore the products to be pickled can appear like material coated by a dark grey layer, e.g. black strip, made of mixed oxides, whose thickness is comprised between fractions of µm and 10 µm maximum. Generally this kind of scale is the easiest to be removed. It is more difficult to remove the scale from materials having been subject to corrosion so as to produce a thick layer of oxides or very deep cavities, even in the range from 50 to 100 µm.

The most widely used process for removing scale from metal products is pickling with acid; this process involves treating the metal products with H_2SO_4 or HCl at a temperature of approximately 80°C for a period of time ranging from 10 to 30 minutes. The thicker the scale layer, the longer the required pickling time; while, the temperature remains constant.

For example, before drawing metal products, the metal is normally cleaned by immersing the coils in a container filled with hot hydrochloric or sulphuric acid. Sulphuric acid mainly eliminates scale by means of a mechanical, rather than chemical, action. The acid is able to penetrate into the metal under the scale layer where it reacts with the iron forming water-soluble iron sulphate and releasing a gas mixture consisting mainly of H_2.

This action detaches the scale from the iron; then, at the end of the pickling process with acid, the surfaces of the metal product are cleaned with high-pressure jets of water.

Temperature control plays an important role in this type of pickling since the speed of the acid-metal reaction is highly affected by temperature; for example, the reaction is 100 times faster at 88°C than at ambient temperature. At the other end of the scale, overheating the acid wastes energy, consumes an excessive amount of acid very quickly, and creates unnecessary fumes that are highly corrosive to the structure of the plant. Not only, acid at high temperatures is also damaging to the surface of the metal: it produces pitting. To help prevent pitting or the excessive decomposition of the metal surface, inhibitors are commonly used. Said

and the use of mildly aggressive cleaning means.

The main phases of this process, disclosed in patents US 6.217.666, its continuation-in-part patetent US 6.406.550 and US 6.402.852, are the heating of the metal product, the reduction of the oxides, and the cooling of the metal product. The scale-reducing stage in the reaction area is carried out ensuring a turbulent and/or vigorous injection of the reducing gas, preferably in the presence of elementary carbon. A disadvantage of these types of processes is that gas flows in a disorderly manner inside the reactor, and hydrogen is supplied taking for granted that it will react with the scale found on the metal product. The presence of the chaotic gas flow inside the reactor limits the speed of reaction and significantly lengthens the descaling process. Furthermore the use of fans to recycle the reducing gas inside the reactor can cause accumulation of gas products issued from the reduction, e.g. H_2O, thus slowing down oxides reduction reactions in the same parts and causing a general reaction slow down and also product non-uniformity.

As a result, the efficiency of the AFP process is greatly reduced; alternatively, to offset this problem and obtain a level of productivity comparable to the one of traditional acid-pickling plants, the process must take place in very long plants. Apart from the inconveniences related to constructing a large plant, the large amount of reducing-gases required for the reactor present a great hazard in the event of an emergency. Furthermore, in very long plants, it is also necessary to take into account the significant amount of time required to fill the plant with the reducing gas, the significant duration of the thermal transient, and the high thermal losses; these factors make the AFP process financially less appealing compared to acid-based pickling processes.

Another problem that generally arises with acid-free pickling processes of the known type is the poorer quality results obtained when treating metal products totally covered with thick and/or highly adhesive scale. In this case, when a piece of metal covered with a uniform, or not, scale layer is fed through an AFP reducing plant, the top scale layer is reduced and the surface looks shiny. However, in many cases, the reduction does not occur throughout the thickness of the scale. In

other cases, the reduction does not occur uniformly making the resulting metal surface not very suitable for further machining. Another drawback is that, the

depression areas, which are repeated in succession along the entire surface of said metal product, the overpressure areas being associated with a reducing gas blowing stage the towards the surface of said metal product, and the depression areas being associated with a reducing gas evacuation phase downstream of the blowing stage, and in that it comprises second control means for controlling reducing gas chemical composition at the blowing stage, means adapted for purging and recycling reducing gas after reducing operation of the scale, third control means for controlling reducing gas temperature.

Preferably, said device includes, among the means for heating the metal product, in combination or alternatively, a microwave device, induction heating elements with or without frequency modulation, naked or screened burners that require oxygen or air in the pre-mixed form or not, gas or electric radiant tubes with amplified radiation, and induction and infrared heating devices.

Furthermore, the device comprises, among the heating means of the reducing gas, ducts made of hot refractory material through which the reducing gas flows or, alternatively or in combination, a heated metal wall licked by the reducing gas.

Generally, the employed reducing gas is suitable for reducing, in its pure form or in combination with other neutral and/or reducing gases, metal oxides.

The apparatus provides for various possibile devices for purifying the reaction gas from reaction products before re-using the same gas: adsorbers, absorbers or cryogenic systems.

Furthermore means are provided for mechanical removal of iron sponge produced from the reduction reaction between reducing gas and oxides forming the scale. Among the means used there are included brushes, abrasive blasting, solid CO_2 injection.

In accordance with another aspect of the invention, the objects of the invention are achieved by means of a dry descaling process for the removal of the scale on the surface of a metal product, which is carried out with the dry descaling apparatus as described above, comprising at least one heating area for heating the metal product, at least one reducing area for performing a reaction between a metal-oxide reducing gas and at least the scale, at least one area for cooling the metal product, first heating means for heating the metal product,

and additionally

- brushing of the product to be treated in case of rust presence,
- choice of organised jets,
- material and gas heating by means of : inductors, burners, radiating pipes, microwaves, IR, NIR.

ii) to overcome the chemical resistances, three main stages of the pickling process are provided, i.e. reactants adsorbtion, reaction and products desorption, during which the invention provides for the following features to improve reduction speed:

- gas temperature (300°C<T<1100°C)
- purity of the reducing gas ($H_2O_{max} = 5\%$)

and additionally

- material and gas heating by means of: inductors, burners, radiating pipes, microwaves, IR, NIR,
- reducing gas purifying and recycling plant by means of adsorption, absorption, cryogenic systems, etc.
- gas feed with specific consumption of $4 \div 100 Nm^3/min*kg_{scale}$.

iii) to overcome the physical resistances in the last part of the process, two main stages of the pickling process are provided, i.e. gas-solid diffusion, and gas-gas diffusion, during which the invention provides for the following features to improve reduction speed:

Choice of an organised reducing gas flow having the features:

- High gas-solid velocity (v>5m/s), high shear stress (>0.03÷5 Pa), high turbulent kinetic energy;
- Evacuation zones for gaseous reaction products, e.g. creation of an underpressure zone (>+2Pa),
- Optimal gas and solid temperatures,

and additionally

- choice of organised jets and provision of zones between jets for reaction products evacuation,
- material and gas heating by means of: inductors, burners, radiating pipes, microwaves, IR, NIR.

Compared to the known pickling process described in patent US-A-6.217.666, the

of pressure oscillations, which follow a regular pattern, on the surface of the metal product. The aim of these disturbancies is both to generate reducing gas feeding zones followed by reaction products evacuation zone and to make the boundary layer unsteady, particularly its laminar sub-layer. In case this layer would be saturated with reaction products, e.g. water vapor, it would inhibit reaction prosecution.

These oscillations are calculated to create a distribution in space that optimizes both the flow of the reducing gas to the surface to be reduced and the immediate removal of the water vapor produced by the reaction. This control is carried out by means of a particularly advantageous configuration of the reactor or of the area of the pickling line where the reaction takes place. This configuration of the reactor facilitates the production of a current along the surface of the metal product with a «piston effect», while the configuration of the channel of the reactor creates an oscillating pressure field fixed in space. By choosing the configuration of the channel of the reactor adequately, it is possible to create pressure oscillations that create a sinusoidal shape or any other type of periodic wave.

In a first version of the channel of the reactor, the channel consists of a series of tubes, with a specific pitch separating them as shown in Fig. 17.

The channel of the flow is realized to ensure maximum efficiency for many different types of scale and the fastest possible processing rate; since the optimal frequency does not vary much with different types of scale and the frequency of oscillation of the pressure, seen from the product that advances, it can be adjusted slightly with small changes to the process speed.

Depending on the nature of the metal product to be descaled, the following value ranges are optimal for the main process variables:

Geometrical pitch (P): from 10 to 1500 mm

Oscillation amplitude of the pressure: from 0,1 to 400 mmH_2O (=0,9806 to 3,922 $\cdot 10^3$Pa)

Oscillation amplitude of the velocity: from 1 to 80 m/sec

Minimum distance between the channel walls and the product: from 2 to 500 mm

The gas velocity at the surface of the product must be greater than 5m/sec, as an average in the boundary sub-layer, in every point of the surface of the product to be treated.

AMENDED CLAIMS

1. A dry descaling apparatus for scale removal from a surface of a metal product comprising
at least one heating area for heating the metal product,
at least one reducing area for performing a reaction between a metal-oxide reducing gas and at least the scale,
at least one area for cooling the metal product,
first heating means for heating the metal product,
second heating means for heating the reducing gas,
means for removing reaction products from the reducing gas after reaction,
means for removing reaction products which are left on the surface of the metal product after treatment, and
means for cooling the metal product;
said dry-pickling apparatus being characterised by the fact that it comprises
first control means (16, 17, B_1, C_1) for fluid dynamic control of the boundary layer produced by the flow of said reducing gas over the surface of said metal product wherein said first control means are adapted for generating regular pressure oscillations comprising overpressure and depression areas, which are repeated in succession along the entire surface of said metal product,
the overpressure areas being associated with a reducing gas blowing stage towards the surface of said metal product, and
the depression areas being associated with a reducing gas evacuation phase downstream of the blowing stage, and in that it comprises
second control means for controlling reducing gas chemical composition at the blowing stage,
means adapted for purging and recycling reducing gas after reducing operation of the scale,
third control means for controlling reducing gas temperature.

2. An apparatus as claimed in claim 1 wherein pressure is above +10 Pa in said overpressure areas and where pressure ranges above –2 Pa in absolute value in said depression areas.

3. An apparatus as claimed in claim 1 wherein said first control means comprise a

plurality of coaxial Venturi (16,17) tubes placed at a reciprocal distance comprised between 10 mm and 1500 mm and having their axis positioned along the conveying direction of the metal product.

4. An apparatus as claimed in claim 1 wherein said first control means comprise a plurality of tube pairs, each tube pair consisting of a heating tube and of a Venturi tube placed downstream of the heating tube, the tubes of the tube pair having axes perpendicular to the surface of said metal product and are placed at a reciprocal distance comprised between 10 mm and 1500 mm.

5. An apparatus as claimed in claim 1 wherein said first control means are positioned at a distance from the surface of said metal product comprised between 2 mm and 500mm.

6. An apparatus as claimed in claim 1 wherein the first heating means comprise a microwave device.

7. An apparatus as claimed in claim 1 wherein the first heating means comprise a heating convective flow of the reducing gas previously heated to a temperature comprised between 300 °C and 1100 °C.

8. An apparatus as claimed in claim 1 wherein the first heating means comprise induction heating elements with or without frequency modulation.

9. An apparatus as claimed in claim 1 wherein the first heating means comprise air or oxygen burners having a naked or screened flame.

10. An apparatus as claimed in claim 1 wherein the first heating means comprise gas or electric radiant tubes.

11. An apparatus as claimed in claim 1 wherein the first heating means comprise amplified radiation heating elements.

12. An apparatus as claimed in claim 1 wherein the first heating means comprise a microwave and/or convective flow device for heating the reducing gas previously heated to a temperature comprised between 300 °C and 1100 °C and/or induction heating elements and/or air or oxygen burners having a naked or screened flame and/or gas or electric radiant tubes and/or amplified radiation heating elements.

13. An apparatus as claimed in claim 1 wherein said second heating means comprise at least one duct of hot refractory material through which the reducing gas flows or at least a metal wall heated electrically or by a flame that is licked by

said reducing gas.

14. An apparatus as claimed in claim 1 wherein said means for cooling the metal product comprise inert or reducing gas forced convection systems.

15. An apparatus as claimed in claim 1 wherein said means for removing the reaction products from the reducing gas, after reaction stage, comprise at least one cryogenic and/or absorption and/or mechanical plant.

16. An apparatus as claimed in claim 1 wherein said means for removing the reaction products remaining on the surface of the treated metal product are placed after the cooling area and comprise mechanical brushing means.

17. An apparatus as claimed in one or more of the previous claims wherein said heating; reducing, and cooling areas are placed in a common chamber including said first and second heating means, said first control means, and said means for cooling the metal product.

18. A dry descaling process for the removal of the scale on the surface of a metal product, which is carried out with the dry pickling apparatus as claimed in one of the previous claims comprising

at least one heating area for heating the metal product,

at least one reducing area for performing a reaction between a metal-oxide reducing gas and at least the scale,

at least one area for cooling the metal product,

first heating means for heating the metal product,

second heating means for heating the reducing gas,

means for removing reaction products from the reducing gas after reaction,

means for removing reaction products which are left on the surface of the metal product after treatment, and

means for cooling the metal product,

the process comprising the following steps:

a) providing a metal-oxide reducing gas,

b) heating the metal product to a first temperature greater than ambient temperature without reducing and without oxidizing the specific surface of the material to be treated,

c) heating the reducing gas to a second temperature greater than ambient

temperature,

d) introducing the metal product in the reducing area,

e) performing the reaction between said metal-oxide reducing gas and at least said scale,

f) cooling the metal product,

g) removing the reaction products from the reducing gas after the reaction with the scale,

h) removing the reaction products from the surface of the treated metal product,

the process being characterized by:

i) controlling fluid dynamics of boundary layer of the flow of the reducing gas over the surface of the metal product by means of first control means (16,17,19, A_1, B_1, C_1) whereby there is provided an organised gas distribution and homogeneous gas concentrations adequate to the amount of the scale found on said surface and sufficient for removing the reaction products from said reducing gas,

j) providing a blowing stage of the heated reducing gas to the surface of said metal product at a predetermined flow rate comprised in the range from 4 to $100 Nm^3/(min \cdot kg_{scale})$,

k) providing a reaction time comprised in the range from 20 to 90 sec. to remove oxygen from the scale,

l) providing, by means of the boundary layer fluid dynamic control means , an evacuation flow of said reducing gas, after it has reacted in accordance with stage k), after said delivery flow, whereby said evacuation flow is associated with a corresponding depression area on the surface of said metal product,

m) performing stages j) and l) cyclically in regular succession along the entire surface of said metal product,

n) removing the reaction products from the reducing gas after the reaction with the scale.

19. A process as claimed in claim 18 wherein the reaction products that remain on the surface of the treated metal product are removed.

20. A process as claimed in claim 18 wherein, at stage j), the concentration of reducing gas produced compared to the scale is comprised between $4 Nm^3/(min\ kg_{scale})$ and $100 Nm^3/(min\ kg_{scale})$.

21. A process as claimed in claim 18 wherein the pressure ranges above +10 Pa in said overpressure areas.

22. A process as claimed in claim 18 wherein in said depression areas the pressure ranges above –2 Pa in absolute value.

23. A process as claimed in claim 18 wherein the reducing gas is used in combination with other inert and/or reducing gases.

24. A process as claimed in claim 18 wherein the reducing gas is hydrogen and the inert gases are preferably nitrogen and/or helium and/or argon.

25. A process as claimed in claim 18 where, in accordance with stage n), water vapor concentration is kept at every point below 5% in volume.

26. A process as claimed in claim 18 wherein the reducing gas is heated to a temperature comprised between 300°C and 1100°C.

27. A process as claimed in claim 18 wherein the heating of the metal product is carried out by microwave radiation and/or a reducing gas heating convection flow and/or by induction and/or by flame and/or by radiation.

28. A process as claimed in claim 18 wherein the heating of the reducing gas is accomplished by means of contact with heated refractory materials and/or heated metal walls.

29. A process as claimed in claim 18 wherein the boundary layer fluid dynamic control is performed by means of a plurality of Venturi tubes that are coaxial, placed at a reciprocal distance comprised between 10 mm and 1500 mm, and have their axis placed along the conveying direction of the metal product.

30. A process as claimed in claim 18 wherein the boundary layer fluid dynamic control is performed by means of a series of tube pairs wherein each tube pair consists of a heating tube and a Venturi tube placed downstream of the heating tube, wherein the tubes of the tube pair have axes perpendicular to the surface of the metal product, and wherein the tubes are placed at a reciprocal distance comprised between 10 mm and 1500 mm.

31. A process as claimed in claim 18 wherein the removal of the reaction products from the reducing gas after reaction is performed by means of a cryogenic and/or absorption and/or mechanical effect.

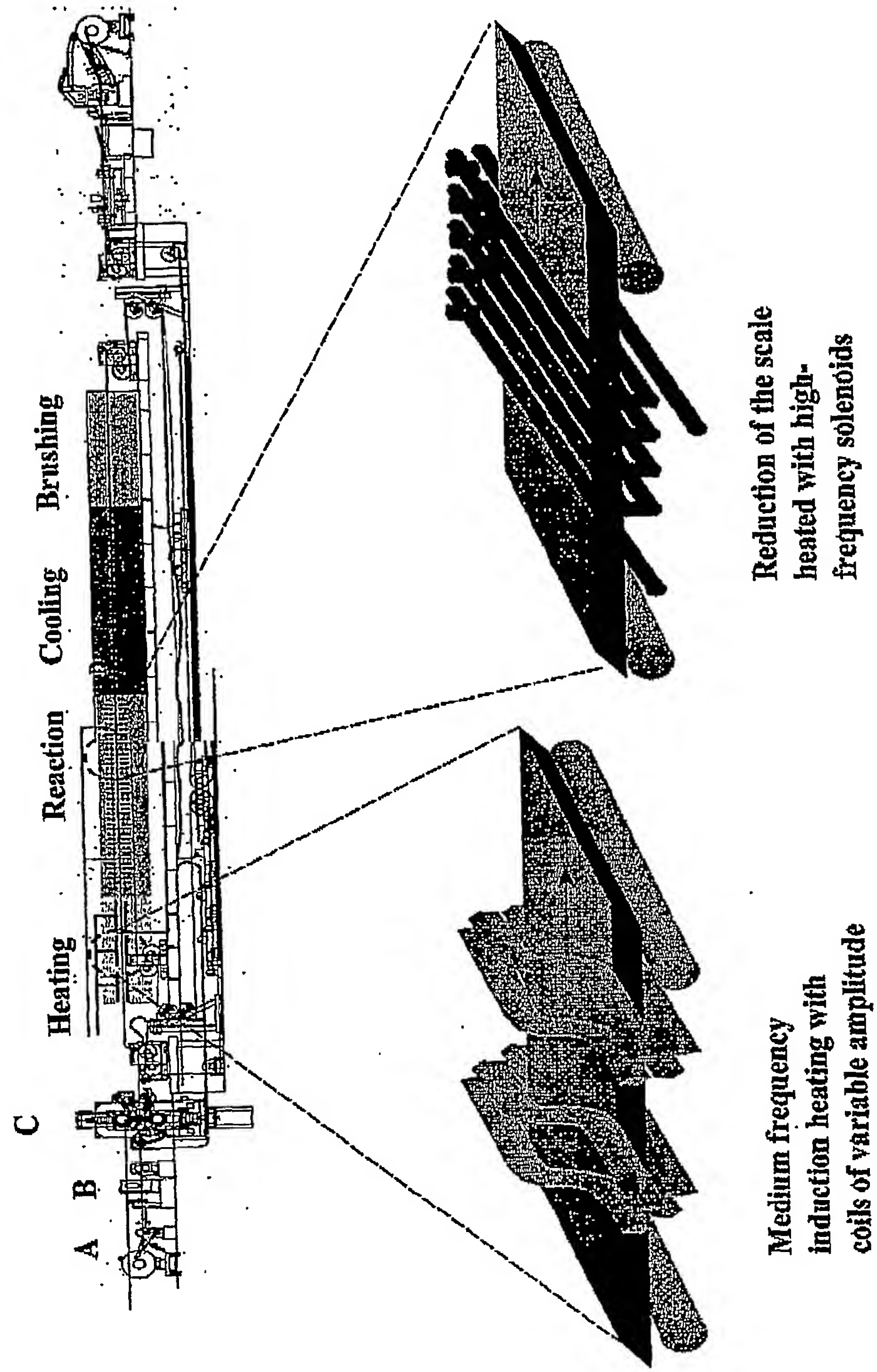
32. A process as claimed in claim 18 wherein the cooling of said metal product is

performed by means of inert gas forced convection.

33. A process as claimed in claim 18 and 30 comprising a step for reinjecting the reducing gas, after the reaction products have been removed, into the cycle.

34. A process as claimed in claim 19 wherein the reaction products found on the surface of said metal product are removed by brushing.

FIG. 11


A
B
C
Heating
Reaction
Cooling
Brushing
Medium frequency induction heating with coils of variable amplitude
Reduction of the scale heated with high-frequency solenoids

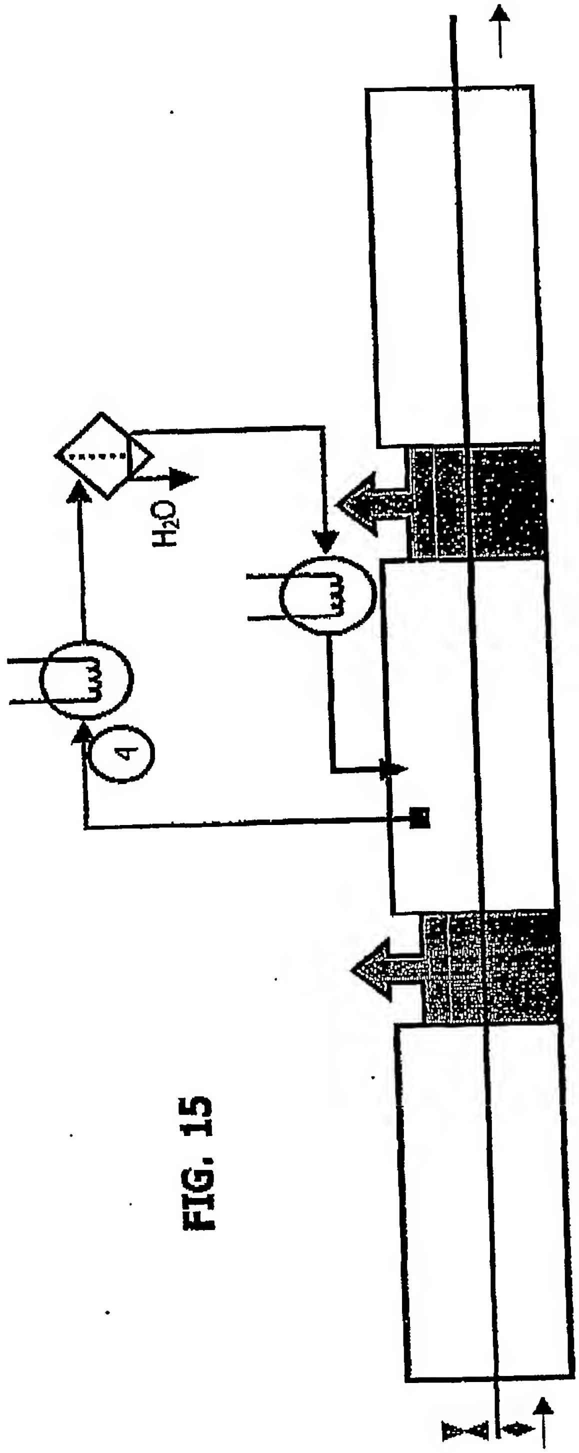


FIG. 15

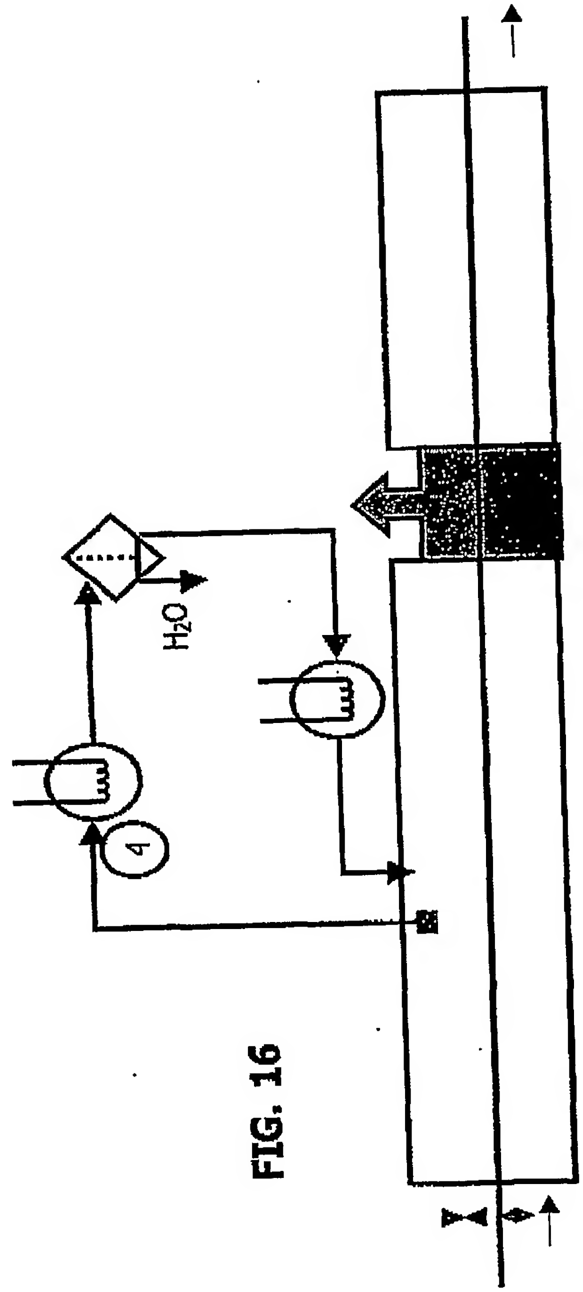


FIG. 16

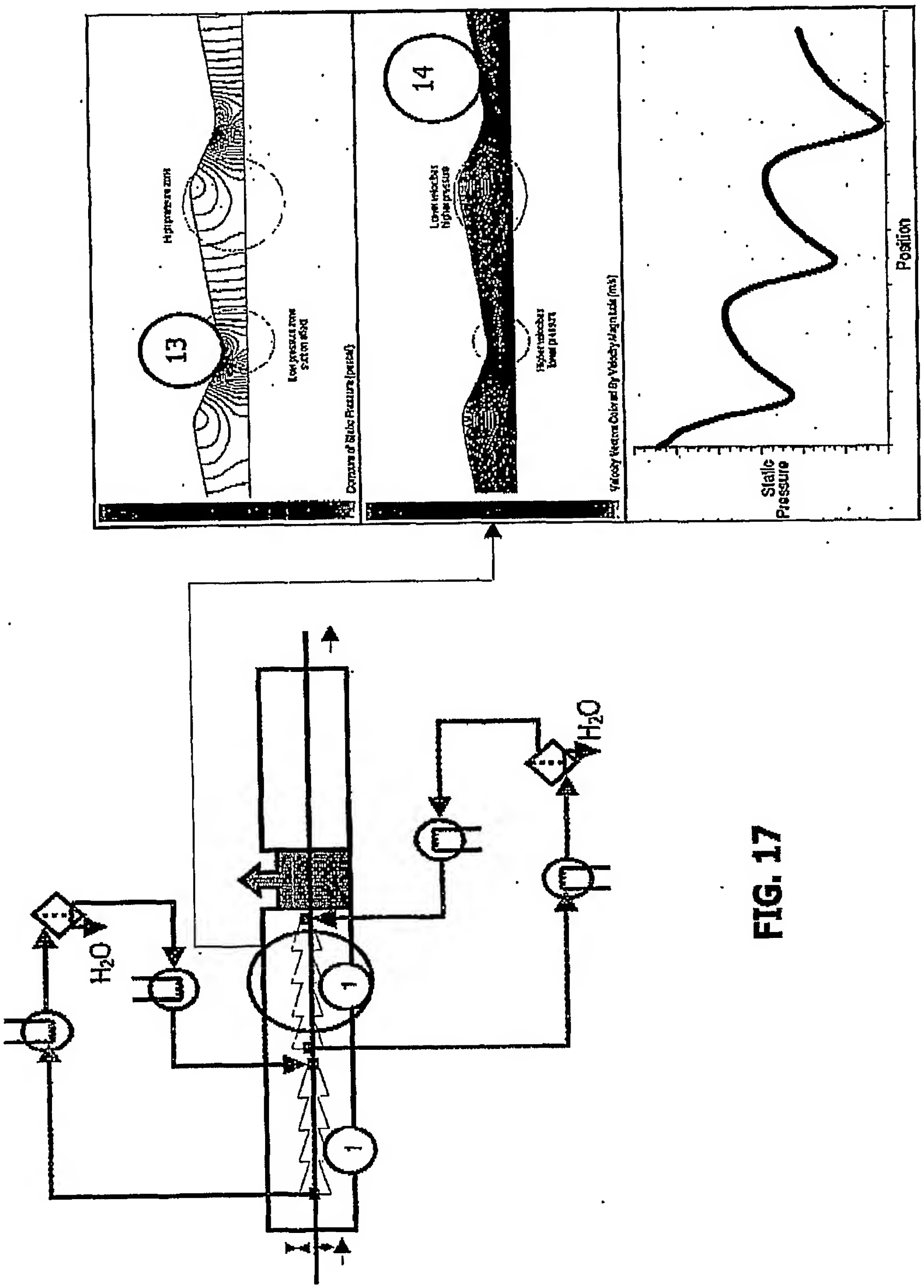
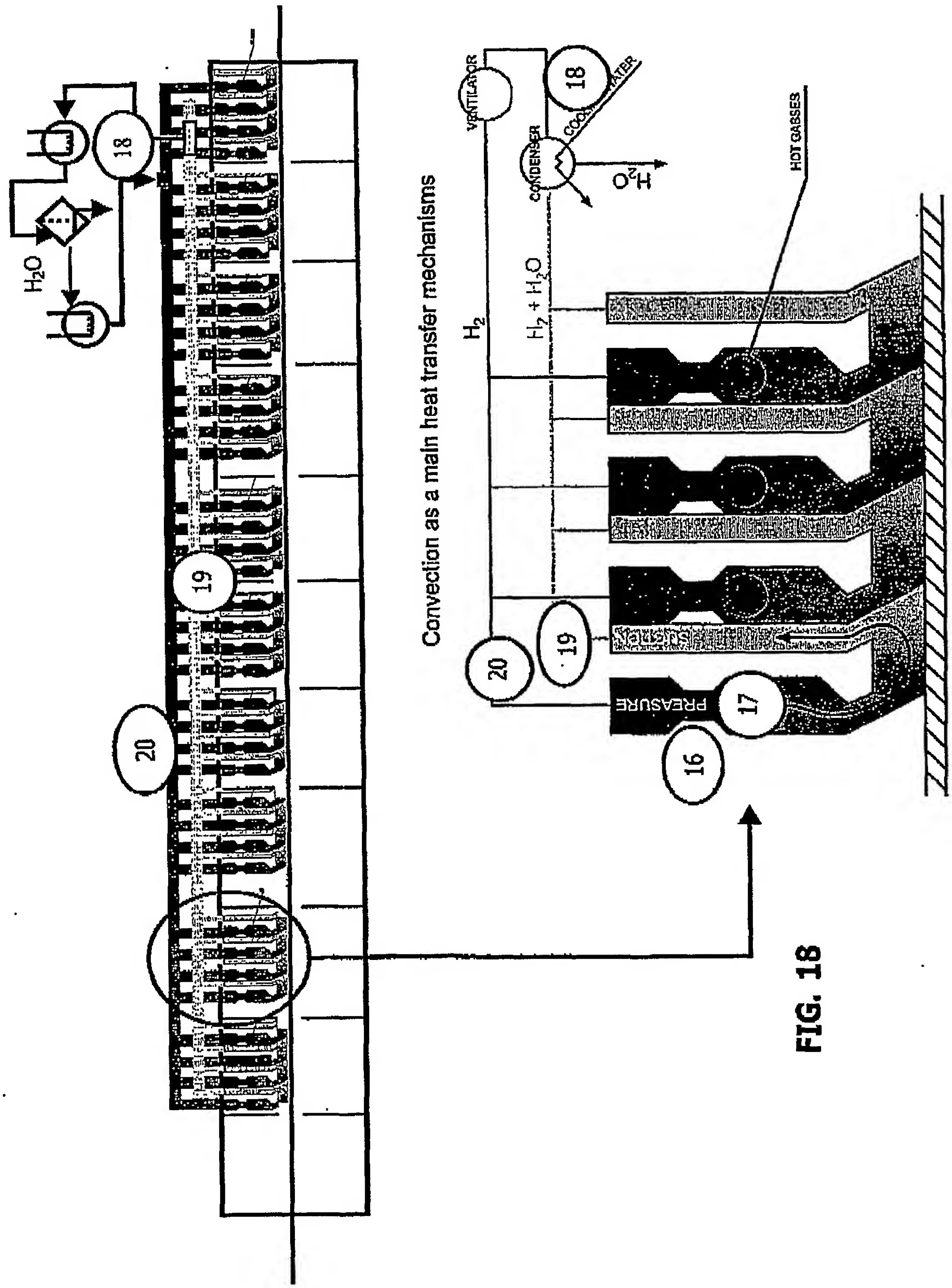


FIG. 17



H2O
18
20
19
Convection as a main heat transfer mechanisms
H2
H2 + H2O
VENTILATOR
CONDENSER
18
H2O
HOT GASSES
20
19
PREASURE
17
16

FIG. 18